Bridging the Gap Between Perception and Reality: A Simulator-Based Study on DUI Risk - Follow-up

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Abstract

Drinking under the influence of alcohol (DUI) is very dangerous and can have a significant impact on society and on the individuals involved and their families. Previous research has shown that alcohol has a clear and relevant impact on driving skills and on the ability of drivers to control a vehicle. Much effort has been devoted to reducing drink-driving. Here, we argue that a way to develop effective interventions is to increase the prospective drivers' awareness of the risk associated with DUI. This should be done with the aim of preventing drink-driving rather than trying to curb it when drivers have already started engaging in it since every trip done without a punishment or negative impact leads to increasing the drivers' underestimation of the risk. In the present study, we conducted a three-phase intervention. In the first phase, we measured the baseline risk perception associated with DUI. In the second phase, on a driving simulator we used a dedicated software to simulate the impact of drink-driving on the control of the vehicles. After the drive, participants reported again their risk perception. Finally, in the third phase, 8 months after the drive on the simulator, we collected a follow-up measure of risk perception. Results showed that risk perception associated with DUI was higher in the follow-up than in the baseline and was moderate by participants' perception of the seriousness of the consequences of driving risk in general. These findings contribute to providing evidence about an additional approach to preventing DUI where we did not ask people to drink any alcohol. It is also a scalable intervention because driving simulators are already available in many driving schools and would simply require the dedicated software.

Keywords: risk perception; drunk driving; safety; driving simulator

Introduction

Drinking under the influence (DUI) of alcohol is a very dangerous behavior that can have important repercussions on society both in terms of economic costs and from a health-related perspective. Because of its impacts the European Commission has set the goal of eliminating DUI injuries and deaths by 2050 (Ecorys, 2021; see also the U.S. Center for Control Disease, 2024 for American data). Furthermore, research has shown that the risk of crashing increases as a function of the amount of alcohol in the blood (*blood alcohol concentration - BAC*; Love et al., 2024). Work by the European Commission reported that about 19% to 26% of fatal car crashes are related to DUI (Zyakopoulos et al., 2021). The European Commission itself concluded that these statistics are likely to be even higher due to underreporting of the actual cases in which a fatal crash was caused by a drunk driver (Ecorys, 2021; see also WHO, 2022). In Italy the rate of DUI related fatal accidents is aligned with international trends although the official data is likely an underestimate as reported by the National Health Bureau (Ministero della Salute, 2022).

These data show that it is important to intervene before drink driving behaviors set in to avoid this habit to develop. For instance, people’s risk perception is more influenced by the probability of an event than by the severity of the consequences resulting in people being unlikely to protect themselves when the likelihood of an accident is low (see Slovic at al., 1978 on people’s unwillingness to wear seat belts). Drivers often adopt a “single trip” risk frame and since the likelihood of an accident on a single car trip is rather low they end up underestimating risk despite the fact that over many car trips the risk is not as low as it seems (Slovic et al., 1978). This is because people have trouble understanding compounding risk. For instance, smokers who focus on a single cigarette at the time underestimate their likelihood of getting cancer and the severity of such a condition (Slovic, 2000).

Therefore, in addition to curbing DUI in current drivers, it would be advisable to study more effective strategies to avoid young people's chance of drink-driving in the first place. Here, we propose that one such strategy could be to sensitize prospective drivers about the risk and to do so in a safe but immersive fashion. To this end, the present project targeted prospective drivers aged 18 to 24 years and adopted an innovative and immersive strategy to increase awareness of the risks of DUI. Specifically, we asked young individuals who were about to take the quiz to receive the driving license to drive on a simulator adapted with a software that simulated the perceptual experience of a drunk driver. We decided to target prospective drivers because they should not have had a chance to drive under the influence of alcohol. If this type of intervention is successful this could significantly reduce their chance to engage in DUI, thus avoiding the development of dangerous behavior.

A meta-analysis by Love and colleagues (2024) showed that DUI is hard to deter. Consistent with the research on risk perception mentioned above, past experience with DUI matched by a lack of consequence is a positive predictor of drink driving, meaning that those drivers who engaged in DUI and were not fined nor involved in accidents are more likely to do it again in the future. Moreover, even when sanctions are applied, they do not seem to deter the past offenders (Freeman et al., 2006a; Freeman et al., 2006b) not considering that in many instances drivers who engaged in DUI report not being subject to any sanction in the first place (Freeman et al., 2021). This evidence suggests that it is fundamental to act before the drivers have a chance to engage in DUI and reinforce their perception that the risk of accidents and fines is low.

Through the use of the driving simulator and a specialty software that replicates the perceptual and motor experience of drink-driving we aimed to increase risk perception and reduce optimistic bias and the illusion of control. These biases can induce young drivers to underestimate the risks associated with DUI. There is evidence that through vivid and direct experience of the consequences of alcohol on driving skills this underestimation can be successfully reduced (Brookhuis et al., 2011), thus promoting awareness and the responsible choice not to drive while intoxicated. Considering the effectiveness of this type of programs, our project aimed to reduce the impact of biases and improve behavior through an experiential methodology in which participants drive on a simulator that mimics driving under the influence of alcohol (vs. in a sober state).

The next section reviews the literature on the effect of alcohol on the skills required to correctly operate a car while the following one describes the cognitive biases that can lead drivers to perceive a low risk associated with DUI. Afterwards, we describe the methodology and results of our study and discuss our findings in relation to the existing literature.

Effect of alcohol on driving

Alcohol can impact driving at different levels of behavior related to driving skills (control, maneuvering, and strategic; Michon, 1985). Different concentrations of blood alcohol concentration (BAC) impact different driving skills although impairment can start at any level above zero BAC (Moskowitz & Florentino, 2000; Li et al., 2019). Moskowitz and Florentino found that at around 0.05 g/dl most driving skills are impaired. Most studies have studied the effect of alcohol on control and tactical levels showing that the impairment depends also on the complexity of the tasks (with complex driving tasks being more affected; Martin et al., 2013).

A line of work that is relevant here is the one that focused on laboratory tests of the impact of alcohol on cognitive functions (see Jongen et al., 2016). Adopting different tests of attention and inhibition (e.g., go/no-go task and divided attention) these studies found impaired functioning at both medium and high BAC levels. However, driving on a simulator was less sensitive to the effects of alcohol on these functions than real world driving is. In general, simulated driving experiments found that alcohol affects swerving, lane crossing, and speed (Jongen et al., 2016; Irwin et al., 2017). For instance, simulated driving studies showed that, at the manoeuvering level, there is a reduction in the ability to respond to dangerous situations and to keep a safe distance from other vehicles although the extent to which this translates in actual dangerous driving could be moderated by contextual factors (e.g., increased time reactions when reacting to the traffic lights versus to a car coming into traffic; Van Dijken et al., 2020). A meta-analysis by Simmons and colleagues (2022) showed that alcohol is associated with outcomes like crashes, lane excursions, time out of lane, speed, and speed variation. The results also indicated a significant variability in these effects, thus suggesting that the impairment caused by alcohol is not consistent but changes across individuals and driving conditions.

These findings are also consistent with a tendency for people to take more risk when under the influence of alcohol (Martin et al., 2013; Weafer & Filmore, 2016; Harmon et al., 2021). A link has also been established between alcohol and impaired decision-making that can result, in the domain of driving, in overestimating one's ability to drive safely, increased acceptance of risk, and the inability to assess the extent of the impairment caused by drinking (Tyska et al., 2015). This is also one of the reasons why in the present work we decided to focus on prospective drivers' risk perception and on a potential way to sensitize them to the extent of the impairment before they had any real chance to engage in DUI.

Risk perception of drink-driving

As we have just seen, alcohol leads to underestimating the risk of drink-driving and to neglect the cognitive impairment in the driver's ability to control the car (Tyska et al., 2015). This is, however, not the only way in which risk perception is related to drink-driving. Drivers have a general tendency to underestimate the risk associated with driving and DUI. Consistent previous studies found that young drivers have unrealistic beliefs about the real consequences of drink driving (De Blasiis et al., 2017; Leung & Starmer, 2005; Potard et al., 2018; Vankov & Schroeter, 2021; Yadav et al., 2022). These unrealistic beliefs appear to be influenced by the distinct cognitive distortions: the illusion of control and the optimistic bias (Vankov & Schroeter, 2021; Vankov et al.,2022).

Specifically, the *illusion of control* consists of the tendency to see the chances of success as higher than the probability warrants (Langer, 1975). Individuals with high illusion of control beliefs tend to overestimate the probability of success associated with their performance and tend to falsely attribute a random outcome to their ability. Research on driver behavior has shown that the illusion of control is also a contributing factor in risky driving behavior (McKenna, 1993; Nees et al., 2021; Stephens and Othsuka, 2014; Svenson, 1981).

Optimistic bias, instead, refers to the decision-makers belief that they are more skilled and less likely to experience negative events than their peers (Weinstein & Klein, 1996). Gosselin and colleagues (2010) found that the optimistic bias effect was consistent in different generations. They not only examined the optimistic bias in three different cohorts, but the authors found that when compared with a greater cohort, the effect of the optimistic bias was higher. In other words, young drivers rated their driving risk as being lower than both their same age peers, and older drivers (Gosselin et al., 2010). Individuals with high levels of optimistic bias, therefore, tend to have biased judgments in favor of the self, and specifically about driving behaviors, DeJoy (1989) argues that it is mainly novice drivers who engage in risky behavior in driving, convinced that their peer group is risk-free.

Both biases fuel a feeling of overconfidence in one's driving abilities and lead individuals to underestimate the weight of random events that may occur in the environment, thus contributing to increased risk-taking by drivers, particularly younger ones (Payani et al 2019; Wohleber & Matthews, 2016). These biases are not the only predictors that could explain young drivers' behaviors. Indeed, referring to the Theory of Planned Behavior (TPB, Ajzen 1991) other factors that can predict the impaired driving behavior among young people are: 1) attitude, or how favorable, or unfavorable, the behavior is perceived to be, 2) subjective norm, or whether important others are perceived as approving or disapproving the behavior of interest, and 3) perceived behavioral control (PBC), or how easy, or difficult, performing the behavior is perceived to be. For this study, we referred to an extended TPB (Vankov & Schroeter, 2021), which included all the demographic variables (gender, age), TPB constructs (instrumental attitude, affective attitude, subjective norm, descriptive norm, self-efficacy and perceived controllability) to assess drivers' intentions to drive under the influence of alcohol or drug (Vankov & Schroeter, 2021).

In line with this theoretical model, some research shows that young and inexperienced drivers between the ages of 18 and 24, especially males, largely overestimate their driving skills by underestimating the risks involved (Brookhuis et al., 2011). However, recent studies have shown promising results of interventions aimed at reducing drunk driving. Some recent studies show that this overestimation of driving abilities by young people can be successfully reduced through specific intervention programs (see Brookhuis et al., 2011). Vividly experiencing the consequences of alcohol on driving skills seems to foster a better understanding of the reduced ability to control the vehicle under such conditions, promoting the conscious and responsible choice not to drive while intoxicated. For example, Brookhuis and colleagues (2011) showed the role that direct experience of drunk driving appears to play in effectively deterring this type of behavior. The authors asked a group of people aged between 18 to 27 years, who obtained the driving license in the previous six months, to drive in a closed circuit under the influence of alcohol. Subsequently, these people showed increased awareness of the dangers of impaired driving and a decreased sense of control. Compared to the studies reviewed so far, our study contributes to the literature by testing a new methodology based on a simulation of driving under the influence rather than having individuals consume alcoholic drinks before driving a real car. By doing so we extend the ability of researchers to study the psychological factors related to driving under the influence as well as the potential for institutions to sensibilize prospective drivers about the risk of drinking and driving. The approach based on the use of driving simulators has also the advantage to be more effective in reaching many drivers. For instance, by placing the simulators in the DMVs it would be possible to reach all drivers since they must go there to obtain their driving license, and it would not require the need to set up a private course to allow intoxicated people to drive in a safe condition. Based on the literature and the above considerations, our project aims to influence risk perception through an experiential method in which participants are asked to get behind the wheel of a driving simulator modified to mimic the state of intoxication. Specifically, we hypothesized that:

H1: After simulating DUI (versus driving in a sober state) participants should show a higher risk perception of DUI and this effect should be maintained over time (after 8 months).
H2a: In the follow-up, participants who perceive a high (vs. low) seriousness of the consequences of negative events associated with driving should perceive a higher risk associated with DUI.
H2b: In the follow-up, the effect of the perception of the seriousness of risk associated with driving on the risk perception of DUI should be moderated by participants' assessment of the likelihood of being stopped by the police when drink-driving. People who perceive a high (vs. low) chance of being stopped should perceive a higher risk of drink-driving regardless of their general perception of the seriousness of the risk associated with driving.

Method

Participants.

One hundred and two participants (48.04% female; mean age 18.77 ± 1.41 years, ranging from 18 to 24) completed all three sessions of the study (baseline, post-test, and follow-up). Overall, 419 participants completed the baseline survey, 239 completed the post-test survey, and 140 participants completed the follow-up survey. However, we found that 38 participants misreported their code in the last survey, and we were unable to associate them with their responses in the earlier sessions thus we could not include them in the analyses.

Participants were part of a pool of driving schools that took them to the local DMV office to undergo a test of their knowledge of the rules of the road. The test is mandatory for all people who want to get a driving license in Italy. Before starting each session, participants were informed that they could leave the study at any moment and get their data deleted. For each session, we obtained participants' consent, and in all the sessions data were collected anonymously. We discarded all participants who did not complete the baseline, post-test, or follow-up surveys. We did not consider in our analysis incomplete answers and/or double answers. Moreover, minors and people who were over 24 years old were excluded from the study because of the selection criteria required to achieve the sample we needed. For the driving simulation session, we had to exclude participants who suffered from epilepsy or photosensitive conditions because they could not use the simulator. The study was approved by the research team's university ethics committee (protocol number: 5235).

Material and procedure.

The study saw the collaboration of different local stakeholders, such as the Police, the DMV office, the chapter of the ACI - Automobile Club d'Italia, and the association of the driving schools operating in town. A description of the materials used for the first two sessions can be found in a previous preprint (available here) and the surveys translated in English can be found here. To collect the data on risk perception, we designed and implemented a survey on Qualtrics and contacted our sample via email. All materials were originally in Italian. The follow-up was collected eight months after the session on the simulator. In the survey, the participants were first asked to give their consent page. Those who denied their consent were redirected to the end of the survey.

For those who gave their consent, the first question they encountered was whether they received the driving license ("*Have you obtained a driving license?*") to which participants answered yes (1) or no (2). Those who answered yes were redirected to a section asking how often they were driving (on a 1= "never" to 5= "every day"), whether they received any fines (e.g., for running a red light or speeding), and whether they had any accidents (and if yes, who was at fault). Finally, these participants were asked whether they had ever driven under the influence. Participants answered on a 4-point likert scale, from 1 ("never") to 4 ("often"). Instead, the participants who reported not having received their license yet were redirected to the next block of question.

We then asked participants to assess their experience with the driving simulator using three questions that were focused on: i) the driving simulator being effective in promoting responsible driving; ii) the driving simulator making participants' aware of the risks of DUI; iii) the driving simulator making it easier for participants to drive on the road (answers were provided on a 10-point scale ranging from 1= "not at all" to 10= "very".

The survey continued asking participants to complete the following questions and scales already administered in the previous sessions: risk perception of DUI (α = .87), illusion of control and optimism bias in relation to DUI and the three subscales of the Dejoy (Dejoy, 1989): seriousness (α = .79), involvement (α = .84), and control (α = .63; for more details on these measure see here).

Results

Descriptive statistics and correlations

Descriptive statistics are reported in Table 1. When looking at risk perception, in both conditions (simulation of DUI versus simulation of driving in a sober state), it was lower in the follow-up than in the baseline. Other variables did not show particularly clear patterns of either increase or decrease across sessions.

Table 1. Descriptive statistics for the main variables in the study.

	Simulation of driving in sober state (N = 44)	Simulation of driving under the influence (N = 58)
Baseline		M (SD)
Risk perception M (SD)	9.43 (.86)	9.15 (.90)

Dejoy seriousness M (SD)	3.72 (.48)	3.80 (.46)
Dejoy involvement M (SD)	2.25 (.72)	2.52 (.97)
Illusion of control M (SD)	1.84 (1.31)	1.86 (1.64)
Optimistic bias M (SD)	3.09 (2.76)	3.69 (3.50)
Chance of a police force check M (SD)	7.09 (2.48)	6.69 (2.92)
Post-test		
Risk perception M (SD)	9.31 (1.01)	9.32 (.93)
Dejoy seriousness M (SD)	3.76 (.50)	3.83 (.42)
Dejoy involvement M (SD)	2.72 (.77)	2.66 (.77)
Illusion of control M (SD)	1.58 (1.30)	1.41 (.97)
Optimistic bias M (SD)	3.48 (2.97)	3.62 (3.27)
Chance of a police force check M (SD)	7.25 (2.61)	6.86 (2.86)
Follow-up		
Risk perception M (SD)	9.03 (1.56)	9.03 (1.14)
Dejoy seriousness M (SD)	3.66 (.58)	3.81 (.49)
Dejoy involvement M (SD)	2.42 (.67)	2.44 (.73)
Illusion of control M (SD)	1.74 (1.09)	1.53 (.86)
Optimistic bias M (SD)	3.18 (2.76)	3.43 (3.07)
Chance of a police force check M (SD)	6.30 (2.75)	7.02 (2.47)
Additional variables		
Gaming frequency N (%)		
Never	19 (43.2%)	14 (24.1%)
Very rarely	11 (25.0%)	17 (29.3%)
Only once or twice per week	8 (18.2%)	11 (19.0%)
3-4 times per week	2 (4.5%)	5 (8.6%)
Very often/every day	4 (9.1%)	11 (19.0%)
Alcohol consumption in last month N (%)		
Never	7 (15.9%)	7 (12.1%)
Once	16 (36.4%)	23 (39.7%)
2/4 times	17 (38.6%)	24 (41.4%)
2/3 times per week	4 (9.1%)	3 (5.2%)
4/5 times per week	0 (0%)	1 (1.7%)
6 or more times per week	0 (0%)	0 (0%)
Number of drinks N (%)		
None	8 (18.2%)	6 (10.3%)
1-2 drinks	27 (61.4%)	39 (67.2%)
3-4 drinks	7 (15.9%)	12 (20.7%)
5-6 drinks	2 (4.5%)	1 (1.7%)
7-9 drinks	0 (0%)	0 (0%)
10 or more drinks	0 (0%)	0 (0%)
Relatives driving under the influence N (%)		
Never	24 (54.5%)	32 (55.2%)
Sometimes	19 (43.2%)	23 (39.7%)
Often	1 (2.3%)	3 (5.2%)
Very often	0 (0%)	0 (0%)

Looking at the correlations, first, we focused on those found in the post-test session (Table 2). Here we can see that risk perception correlates positively with the score on the seriousness subscale of the Dejoy. The correlation was slightly higher for participants who simulated the DUI condition (*r* = .47, *p* < .001) than for those who simulated driving in a sober state (*r* = .37, *p* < .01).Risk perception was higher for participants who had a lower optimistic bias when simulating the drive in a sober state (*r* = -.50, *p* < .01) than for those simulating a DUI condition (*r* = -.16, *p* = n.s.). In contrast, participants who simulated a DUI condition perceived a higher risk perception when they reported a lower illusion of control after the test on the simulator (*r* = -.37, *p* < .001), whereas the same correlation was much lower for those in the sober condition (*r* = -.16, *p* = n.s.). Finally, in both conditions, risk perception was higher when participants reported a higher likelihood of being stopped by police when driving drunk (respectively, *r* = .34, *p* < .05 in the sober condition and *r* = .36, *p* < .01 in the DUI condition).

Table 2. Post-test correlations for the two driving simulation conditions: sober state (above the diagonal) and DUI (below the diagonal).

	1.	2.	3.	4.	5.	6.	7.	8.
1. Risk perception	--	.37**	.09	-.16	-.50**	.34*	-.09	.11
2. Dejoy seriousness	.47***	--	.28	-.35**	-.21	.37*	.07	.22
3. Dejoy involvement	-.04	-.09	--	.13	-.08	-.08*	-.06	-.18
4. Illusion of control	-.37***	-.19	-.07	--	.26	-.31*	-.01	-.29
5. Optimistic bias	-.16	-.14	.17	-.11	--	-.17	-.02	-.01
6. Chance police checks	.36**	.01	.10	-.12	-.09	--	-.02	.45**
7. Duration	.13	-.12	.15	-.08	-.01	.26	--	.12
8. Points lost	-.15	-.03	.09	.02	.02	.09	-.01	--

Note: * *p* < .05; ** *p* < .01; *** *p* < .001.

In the follow-up, we found a higher correlation between risk perception and the seriousness subscale of the Dejoy for participants simulating a drive in a sober state (*r* = .77, *p* < .001), whereas the same correlation was slightly lower for those who simulated a DUI condition (*r* = .38, *p* < .01). In both conditions, risk perception was negatively correlated with illusion of control (respectively, *r* = -.33, *p* < .05 for the sober condition and *r* = -.43, *p* < .001 for the DUI condition). Finally, in both conditions, risk perception was higher when participants reported a higher chance of being stopped by police when driving under the influence (respectively, *r* = .45, *p* < .01 for the sober condition and *r* = .33, *p* < .05 for the simulation under the influence).

Table 3. Follow-up correlations for the two driving simulation conditions: sober state (above the diagonal) and DUI (below the diagonal).

	1.	2.	3.	4.	5.	6.
1. Risk perception	--	.77***	.25	-.33*	.02	.45**
2. Dejoy seriousness	.38**	--	.37*	-.16	04	.32*
3. Dejoy involvement	.29	.14	--	.13	.17	.26
4. Illusion of control	-.43***	-.44***	-.22	--	.19	.12
5. Optimistic bias	.01	-.03	01	.16	--	.11
6. Chance of police checks	.33*	.10	.20	-.01	.24	--

Note: * *p* < .05; ** *p* < .01; *** *p* < .001.

Regression analyses

We first restructured the dataset in long form to be able to test the three sessions as a within-subjects factor. Afterwards, we run four within-subjects linear regression models in R (R Core Team, 2020) using the *'lme4'* package (Bates et al., 2015). In all model, we included a factor for the random intercept to account for the random effect of the participants.

In the first model, we included the condition (sober vs. DUI), the session (baseline, post-test, follow-up), and their interaction as predictors, duration of the session on the simulator and gender as covariates, and risk perception as dependent variable. In the second model, we added the two-way interactions of condition and session with the seriousness subscale of the Dejoy. In the third model, we tested the effect of the three-way interaction between condition, session and the seriousness subscale of the Dejoy. Finally, in the fourth model we added illusion of control, optimistic bias, and the likelihood of being stopped by police as covariates while keeping the three-way interaction (Table 4). In all models, since session is a three-levels factor, we coded it according to two different contrasts: Contrast 1 compared the first two sessions (baseline and post-test, both coded -1) with the follow-up (coded 2); Contrast 2 compared the baseline (coded -1) with the post-test (coded 1). We decided to test these two contrasts because the focus of this paper is on the effects of the follow-up compared to the earlier sessions.

Results for the first model revealed a significant effect of the Contrast 1 for the session variable ($X^2 = 5.41$, $b = -.11$, $SE = .05$, $t = -2.23$, $p = .03$) and an effect of gender ($X^2 = 7.29$, $b = .44$, $SE = .16$, $t = 2.70$, $p = .01$), whereas the interaction between condition and session was not significant for either of the two contrasts. No other effect was significant. In the second model, we found significant effects of the Contrast 1 for the session variable ($X^2 = 16.51$, $b = -.96$, $SE = .24$, $t = -3.96$, $p < .001$), and for the seriousness subscale of the Dejoy ($X^2 = 41.39$, $b = 1.05$, $SE = .16$, $t = 6.43$, $p < .001$). Importantly, the interaction between these two variables was also significant when considering Contrast 1 ($X^2 = 14.37$, $b = .24$, $SE = .06$, $t = 3.70$, $p < .001$). In the third model, we replicated the same effects but, critically, the three-way interaction between session (Contrast 1), condition, and the seriousness subscale of the Dejoy was significant as well ($X^2 = 17.53$, $b = -.52$, $SE = .12$, $t = -4.19$, $p < .001$). Finally, in the fourth model, we found again the significant three-way interaction ($X^2 = 20.56$, $b = -.56$, $SE = .12$, $t = -4.68$, $p < .001$; Figure 1) while also finding significant effects for two of the three covariates we added (respectively, $X^2 = 10.76$, $b = -.14$, $SE = .04$, $t = -3.28$, $p < .001$ for illusion of control and $X^2 = 27.87$, $b = .10$, $SE = .02$, $t = 5.28$, $p < .001$ for the likelihood of being stopped by police while driving under the influence). These effects show that risk perception increases when participants anticipate a higher chance of being stopped by police, whereas it decreases for participants who have a higher illusion of control.

To better understand the three-way interaction, we ran a simple slopes analysis. In the baseline, the effect of the Dejoy was significant for participants who would afterwards simulate the drive under the influence ($b = .58$, $SE = .23$, $t = 2.48$, $p = .01$, *95% C.I.* [.12, 1.04]) but not in the other condition ($b = .27$, $SE = .25$, $t = 1.08$, $p = .28$, *95% C.I.* [-.22, .76]). The same was true in the post-test session where the effect of the Dejoy was significant for people in the DUI condition ($b = .86$, $SE = .25$, $t = 3.43$, $p < .001$, *95% C.I.* [.37, 1.36]) but not for those in the sober condition ($b = .35$, $SE = .24$, $t = 1.44$, $p = .15$, *95% C.I.* [-.13, .83]). In the follow-up session, the effect of the seriousness subscale of the Dejoy was significant in both conditions (respectively, $b = .57$, $SE = .22$, $t = 2.59$, $p = .01$, *95% C.I.* [.14, .99] for the participants who simulated the DUI condition and *b* = 1.84, *SE* = .21, *t* = 8.82, *p* < .001, *95% C.I.* [1.43, 2.25] for the participants who simulated driving sober). Interestingly, the effect was now larger for the group exposed to driving in a sober state, thus indicating an opposite trend in this session compared to the previous ones.

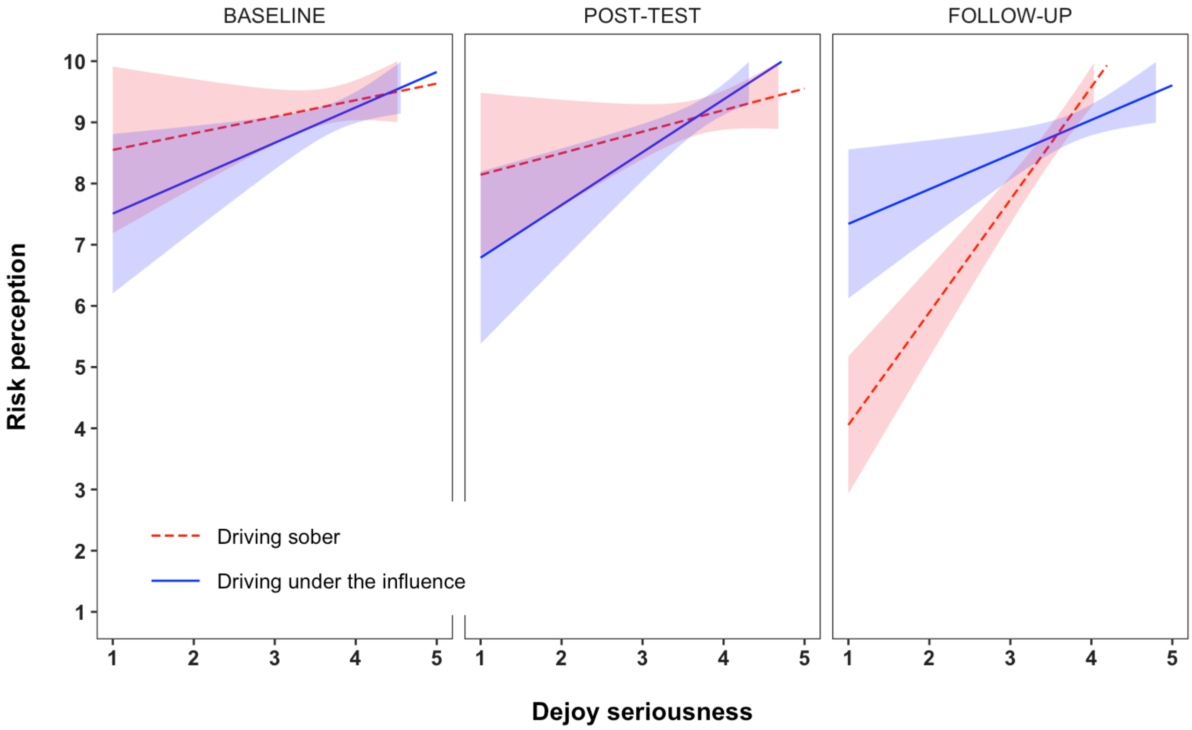

Figure 1. Three-way interaction between session, condition, and the seriousness subscale of the Dejoy.

Table 4. Within-subject linear regression models.

	(1)			(2)			(3)			(4)		
	β	*b (SE)*	*95% C.I.*	*β*	*b (SE)*	*95% C.I.)*	*β*	*b (SE)*	*95% C.I.*	*β*	*b (SE)*	*95% C.I.*
Intercept	.00	8.80*** (.20)	[8.41, 9.20]	.00	5.09*** (.61)	[3.89, 6.29]	.00	5.39*** (.60)	[4.21, 6.57]	.00	5.63*** (.59)	[4.489, 6.79]
Condition (sober = 0; drunk =1)	.03	.07 (17)	[-.26, .40]	.56	1.21 (.88)	[-.54, 2.98]	.36	.79 (.87)	[-.93, 2.52]	.21	.45 (.81)	[-1.15, 2.08]
Session (Contrast 1)	-.15	-.11** (.05)	[-.21, -.01]	-1.26	-.96*** (.24)	[-1.44, -.49]	-2.55	-1.94*** (.33)	[-2.59, -1.29]	-2.55	-.1.94*** (.32)	[-2.57, -1.32]
Session (Contrast 2)	-.05	-.06 (-09)	[-.23, .12]	-.27	-.35 (.46)	[-1.27, .56]	-.33	-.44 (.64)	[-1.70, .83]	-.18	-.24 (.62)	[-1.46, .97]
Gender (Male = 0; Female = 1)	.20	.44** (.16)	[.12, .76]	.10	.21 (.14)	[-.07, .49]	.11	.23 (.14)	[-.04, .51]	.10	.21 (.13)	[-.04, .46]
Duration	.13	.05 (.03)	[-.008, .12]	.10	.04 (.03)	[-.01, .10]	.10	.04 (.03)	[-.01, .09]	.06	.03 (.02)	[-.02, .07]
Dejoy seriousness				.47	1.05*** (.16)	[.73, 1.37]	.44	.97*** (.16)	[.66, 1.29]	.37	.82*** (.15)	[.52, 1.12]
Illusion of control										-.16	-.14*** (.04)	[-.23, -.06]
Optimistic bias										-.03	-.01 (.02)	[-.06, -.04]
Police stop										.24	.10*** (.02)	[.06, .13]
Condition x Session (Contrast 1)	.05	.05 (.07)	[-.09, .18]	-.01	-.01 (.06)	[-.14, .11]	1.93	1.95*** (.47)	[1.02, 2.88]	2.03	2.06*** (.45)	[1.16, 2.95]
Condition x Session (Contrast 2)	.08	.15 (.12)	[-.08, .38]	.09	.15 (.11)	[-.06, .36]	.06	.10 (.90)	[-1.66, 1.87]	-.15	-.26 (.86)	[-1.96, 1.44]

Condition x Dejoy seriousness	-.62	-.35 (.23)	[-.81, .11]	-.42	-.24 (.23)	[-.69, .22]	-.27	-.15 (.21)	[-.58, .27]
Session (Contrast 1) x Dejoy seriousness	1.19	.24*** (.06)	[.11, .37]	2.50	.50*** (.09)	[.33, .68]	2.54	.51*** (.09)	[.34, .68]
Session (Contrast 2) x Dejoy seriousness	.22	.07 (.12)	[-.17, .31]	.28	.10 (.17)	[-.24, .43]	.12	.04 (.16)	[-.28, .36]
Condition x Session (Contrast 1) x Dejoy seriousness				-1.99	-.52*** (.12)	[-.77, -.28]	-2.13	-.56*** (.12)	[-.80, -.33]
Condition x Session (Contrast 2) x Dejoy seriousness				.02	.01 (.24)	[-.46, .47]	.22	.10 (.23)	[-.35, .55]

Additional analyses

In addition to the analyses comparing the results across the three, longitudinal sessions of the study, we run a series of linear regressions on the responses collected in the follow-up. The goal was to better understand which variables predict risk perception eight months after the test on the simulation, once the participants had received the driving license and started driving on the road. We could not do this in the within-subjects models because some questions were presented only in the follow-up.

In the first model, we included as predictors the two Dejoy subscales (seriousness and involvement) with risk perception as the dependent variable. Results showed that the seriousness subscale was the only one that was associated with risk perception in the follow-up session (β = .76, *b* = 1.43, *SE* = .21, *t* = 6.84, *p* < .001, *95% C.I.* = [1.01, 1.84]). We therefore left the involvement subscale out of the subsequent models. In the second model, we kept the seriousness subscale of the Dejoy and added to the predictors participants' perception of the likelihood of being stopped by police while DUI, the frequency with which they drove (participants who had not yet got the driving license were kept in the analyses with a value of zero), gender, and the three questions on the effect of the driving simulation: i) increased responsible driving, ii) increased awareness of the risk, and iii) made it easier to drive on the road. Finally, we included in the model the interaction between the seriousness subscale of the Dejoy and the perceived likelihood of being stopped by police. Results revealed a significant effect of the interaction[1] (β = -.28, *b* = -.20, *SE* = .06, *t* = -3.42, *p* < .001, *95% C.I.* = [-.32, -.08]; see Figure 2). The score on the seriousness subscale of the Dejoy was always positively associated with risk perception but this relationship increased when participants perceived the likelihood of being stopped by police as lower. Consistent, a slope analysis showed that the effect of the seriousness subscale was significant for participants who perceived a low chance to be stopped by police (*b* = 1.44, *SE* = .22, *t* = 3.47, *p* < .001, *95% C.I.* = [.001, .67]), but not for those who perceived this event as more likely (*b* = .39, *SE* = .33, *t* =1.197, *p* = .24, *95% C.I.* = [-.26, 1.05]). Finally, we tested a third model where we added illusion of control and optimism bias among the predictors, while keeping the interaction between the seriousness subscale of the Dejoy and the perceived likelihood of being stopped by police. Results revealed a significant effect of illusion of control (β = -.37, *b* = -.38, *SE* = .11, *t* = -3.61, *p* < .001, *95% C.I.* = [-.59, -.17]) but not of the optimism bias (β = .08, *b* = .03, *SE* = .03, *t* = .79, *p* = .43, *95% C.I.* = [-.04, .09]). The interaction was still significant (β = -.34, *b* = -.25, *SE* = .06, *t* = -4.33, *p* < .001, *95% C.I.* = [-.36, -.13]).

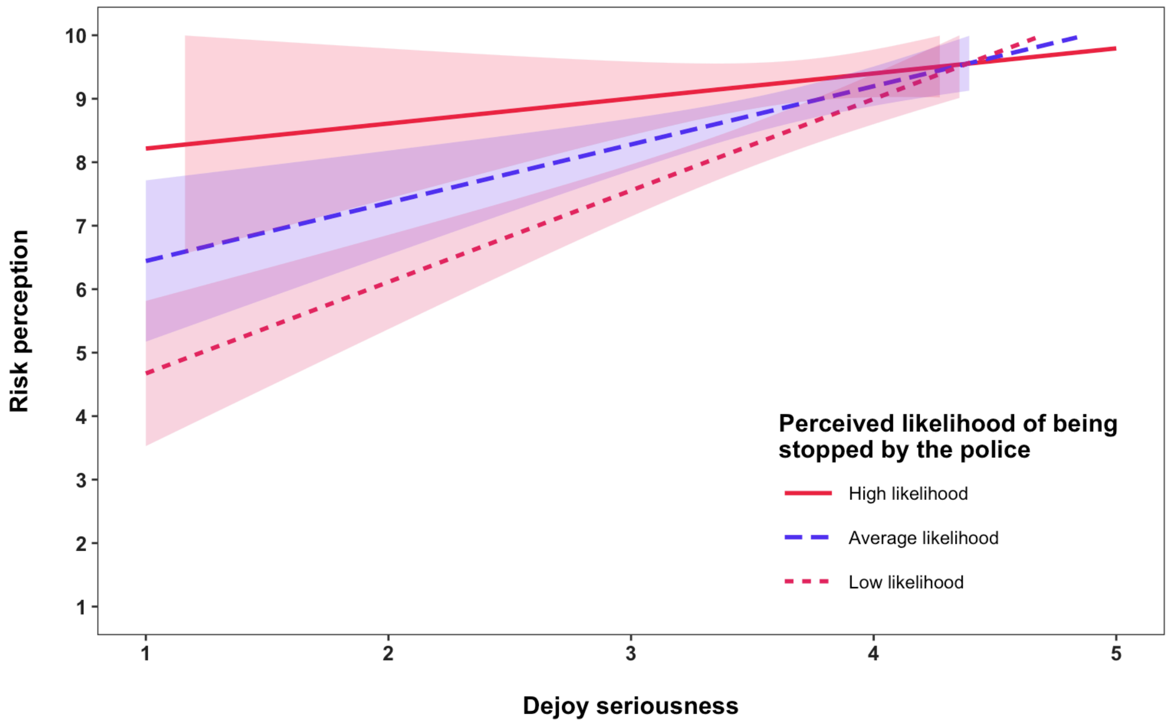

Figure 2. Interaction between the seriousness subscale of the Dejoy and the perceived likelihood of being stopped by police with risk perception in the follow-up session as the dependent variable.

Discussion

We set up a study to increase prospective drivers' awareness of the risk of driving under the influence of alcohol. In doing so, we tried to make our intervention as ecological as possible while maintaining the maximum safety for the participants. We also tried to find a time in which young individuals seeking to get the driving license could be the most sensitive to information about the impact of alcohol on the ability to drive a car safely. Thus, we asked participants to do a drive on a simulator where they could be randomly assigned to one of two experimental conditions: one in which they were simulating a drive while sober or one in which they were simulating a drive under the influence of alcohol. The simulation of the DUI conditions did not involve consuming alcoholic drinks, rather we used a special software in which we could set specific levels of drunkenness and simulate accordingly the slow reactions that alcohol ingestion would produce; this was achieved reducing the promptness with which the driver's inputs on the car controls (steering wheel and pedals) translated in actual actions by the car on the simulator screen, thus replicating the slowed reactions and impaired perceptions experienced in DUI conditions.

To assess the impact of the test on the simulator, we asked participants to complete a survey at three different times: before the drive on the simulator (baseline), immediately after the drive (post-test), and eight months later (follow-up). The surveys asked participants for their perception of the risk of driving generally and of DUI specifically.

We found that risk perception associated with driving under the influence varied across the three sessions and depended on which condition participants were exposed to (sober vs. DUI). Furthermore, the perception of the risk of driving under the influence was associated with the score on the seriousness subscale of the Dejoy (Dejoy, 1989). Results revealed a three-way interaction indicating that, when participants were simulating a drive in a sober state, the impact of the seriousness subscale of the Dejoy on participants' perception of the risk increased across sessions. Its effect was higher in the follow-up after eight months than in the previous two sessions. Instead, the same pattern was not observed in the DUI condition. In the DUI condition, participants always perceived a higher risk associated with DUI when they also perceived a general higher severity of other events than can happen on the roads (e.g., scraping the side of the vehicle at the toll booth) and this relationship did not change significantly across sessions. We found these results even while controlling for gender, length of the test on the simulator (it could end early if the participant broke too many rules of the road), illusion for control, optimism bias related to DUI, and subjective assessment of the likelihood of being stopped by police while driving under the influence. These results are important because they show that simulating a drive in a sober state could lead prospective drivers to underestimate the risk of DUI when they do not have a general sense that driving could lead to serious consequences. This is not an obvious finding since DUI is inherently different from other risk factors of driving since it entails the impact of a behavior (drinking) that is not directly related to driving (unlike running a red light, crashing or scraping a side of the car).

Furthermore, the main aim of this study was to increase the perception of the risk associated with DUI by allowing participants to experience such a condition on a driving simulator. Results showed that the simulation of DUI had the expected effect but only after eight months and not immediately after the drive on the simulator. Both at baseline and in the post-test, participants in the DUI condition were less likely to see it as risky when they did not see driving as risky more generally. However, after eight months and after starting to drive on real roads, these participants perceived the risk associated with DUI as higher than those who simulated a drive in a sober state and this was true specifically when their perception of the risk of driving more in general was low. These results suggest that, overtime, the drive on the simulator led to a decoupling of the perception of the risk of driving and that of DUI more specifically, particularly for participants who perceived a low risk of driving.

Additional analyses were dedicated only to the follow-up session and included a set of variables that were measured only in that session. At a time in which most participants had already got their driving license and had started driving, we found that their perception of the risk associated with DUI was significantly impacted by both how likely they thought they could be stopped by police while driving under the influence and by the seriousness subscale of the Dejoy. When participants judged the likelihood of being stopped by police as low, their perception of the risk of driving under the influence was significantly higher if they had a high score on the Dejoy (general risk perception of driving), whereas the same effect was not significant for those who thought it more likely that police could stop them while driving drunk. The three-way interaction including the condition was not significant. These results suggest that it may be important to make sure that people perceive a high chance of being stopped by police. Otherwise, the likelihood of engaging in DUI would be a function of their perception of the risk of driving, a subjective dimension that can vary considerably in the population of drivers.

This pattern of results emerged in the follow-up session, when participants were already driving, thus future work should investigate if drivers' perception of the likelihood of being stopped is related to experiences they had on the road, the heightened fear associated to a real behavior (vs. a hypothetical one), or a reaction that people have in a more stable way. We are unable to answer this question with the current data, but we think it is important to deepen the understanding of this point, potentially including drivers of all ages and not just those who had just received their driving license. By assessing all drivers, it would be possible to see if this perception changes depending on how long a person has been driving and to understand whether being stopped in the past can influence the responses. For instance, there is work in the domain of tax evasion showing that when people get checked they perceive a lower chance of being checked again (Mittone et al., 2017).

Limitations and future directions

The main limitation of the study is certainly the small sample size. While in a longitudinal design it is normal to have some friction, we expected to reach a higher number of participants in the follow-up. Unfortunately, this issue was conflated by several participants who reported their identification code incorrectly in the follow-up making it impossible to use their data. Despite the collaboration of the local DMV office, city council, and driving schools it was not possible to reach a larger number of participants at baseline, something that would have allowed us to manage this level of friction more effectively. Future work should aim at replicating these results with a larger sample. In addition to reaching more participants at baseline, other possible improvements could be to have more than two simulators available to increase the sample size in the experimental session and to collect follow-up measures both three and six months after the drive on the simulator to keep participants engaged.

In addition, our study was based on a single drive on the simulator, but it could be argued that completing a few drives could strengthen the effectiveness of the intervention even more - or lead to adaptation thus creating an effect that goes against our hypotheses. Even this last possibility would be a worthwhile finding that could help understand the boundaries of how effective (or counter effective) simulated drives could be to reduce DUI. Along a similar line, an intervention that can leverage the use of a higher number of simulators would certainly strengthen the intervention making it more relevant to inform policy making. Simulators are becoming both more reliable in replicating real world road driving and cheaper. More and more driving schools are using them to increase the chances that prospective drivers must train and learn to use car controls in a proper way (Martín-delos Reyes et al., 2019). This could allow future studies collecting data directly in the driving schools where it could be possible to simulate driving under the influence several times or to collect data for the DUI condition and the control condition within-subject instead of between-subject like we did here. This would increase the validity of the findings by eliminating differences between groups at baseline. In our study, at each time slot, we had to deal with batches of 15-20 prospective drivers that took the quiz at the same time, thus making it impossible to have all of them drive on the simulator because some would have to wait for more than an hour. A dedicated space with more personnel and simulators would help to reach an even larger group of people.

Regarding the DUI simulation, one of the modifications to the software was to delay and exaggerate the effect of the inputs made by the driver to replicate the slowed reaction times of drunk drivers. Of course, this is the opposite of what happens when a driver is under the influence. In a real-world scenario, the impaired reaction times and presence of mind would lead to delayed reactions to what is happening on the road. However, manipulating the way the controls react is the easiest solution to simulate DUI, maybe apart from making the drivers drink alcohol. Still, future work may try to make the experience even more real, potentially increasing the effectiveness of the simulation and its ability to raise awareness for the potential consequences of DUI. In this respect, a possible direction would be to use virtual reality (VR) to create an even more immersive experience. We considered this option when planning the study but ultimately decided against it on the basis that it would have required a longer training session, and that VR could make some people feel sick if they are not used to it.

Despite these limitations, we believe that our work provides an important contribution to the literature showing that driving simulators can be used with goals that go beyond the mere teaching of how to operate the controls of a car. Developing software that simulates the experience of being under the influence could be an effective way to increase prospective drivers' perception of the risk in a safe and controlled environment. Furthermore, it does not require the drivers to drink alcohol or to set up a private course to ensure that participants would drive in safe and controlled conditions.

Footnote

[1] We also tested a model including the three-way interaction between Dejoy seriousness subscale, likelihood of being stopped by police, and condition but it was not significant, *β* = .25, *b* = .18, *SE* = .14, *t* = 1.27, *p* = .21, *95% C.I.* = [-.36, -.13].

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